S33

Radiation hydrodynamic simulation of a high-brightness 13.5-nm EUV microplasma

Hiroyuki Hara[1], Goki Arai[1], Takanori Miyazaki[1], Thanh-Hung Dinh, Takeshi Higashiguchi[1], and Atsushi Sunahara[2]

[1]Utsunomiya University, Japan, [2]Institute for Laser Technology (ILT), Japan

Contact e-mail: higashi@cc.utsunomiya-u.ac.jp

1. Introduction

We investigated the feasibility of using EUV emission from a microplasma at 13.5 nm as a high-brightness metrology source. Compared with the HVM case specific requirements for metrology sources have not yet been defined. The light source needs to be stable, small with an etendue in the order of 0.03 mm^{2}sr, and high-brightness with a few watts of power. The microplasma for a metrology source should be produced to be the order of 10 μm with a millijoule per pulse. We show a proof-of-principle experiment using a micro-dot-target with a diameter of 10 μm with a thickness of 100 nm-1 μm, and the results are supported by numerical simulation.

2. Concept for microplasma source

Type	Source Power (W)	Collection Angle (sr)	Source Radius (μm)	IF Power (W)	Etendue (mm²·sr)	Brightness (kW/mm²·sr)	Repetition Frequency (Hz)
HVM	720	5	100	180	1.5 x 10⁻¹	1.2	10 x 10³
Metrology	10	1	10	1.5	3 x 10⁻⁴	5	30 x 10⁶

The metrology source has been demonstrated. However, the power was measured to be 1 mW at IF by use of a 10-W laser.

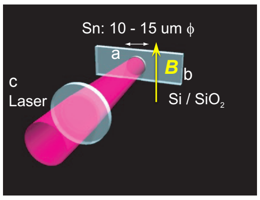


Fig. 1. In order to reduce the plasma expansion and keep the source size in the order of 10 μm, we propose the use of ps laser pulse, together with the microdot Sn targets.

2-a. Preparation of volume-limited Sn targets

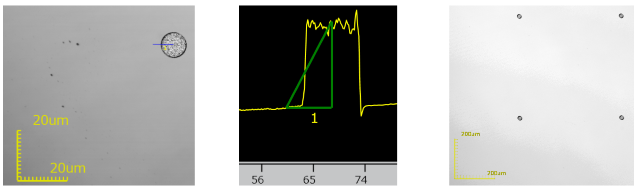


Fig. 2. Photographs of the volume-limited targets with a diameter of 10 μm & the thickness of 150 nm.

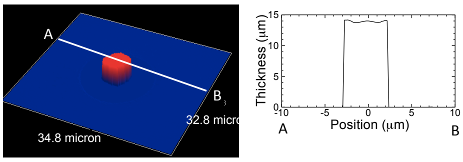


Fig. 3. Example of the 14-μm thickness dot target with a diameter of 5 μm.

2-b. Magnetic field evaluation for mitigation

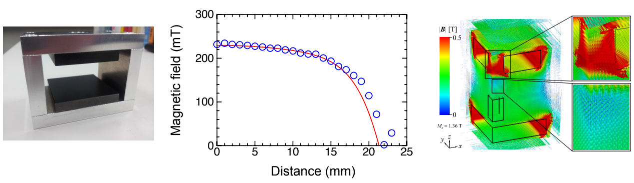


Fig. 4. (a) Photograph of the permanent magnet of 1.2 T. (b) The distribution of the magnetic field in the source position between plates. Maximum magnetic field was 0.2 T. The solid line shows the numerical evaluation by use of the finite element method (FEM), such as right figure.

2-c. Laser pulse irradiation: Spectrum

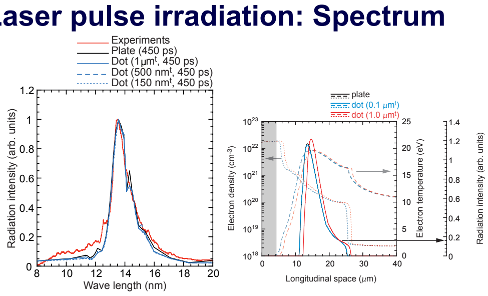


Fig. 5. (a) Spectral comparison at the pulse durations of 150 ps at a laser wavelength of 1064 nm. The conversion efficiency was observed to be CE ~ 1-1.2%.

3. Numerical evaluation for EUV emission

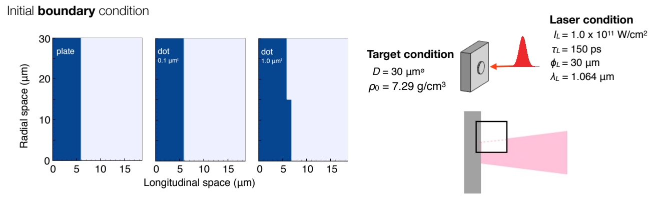
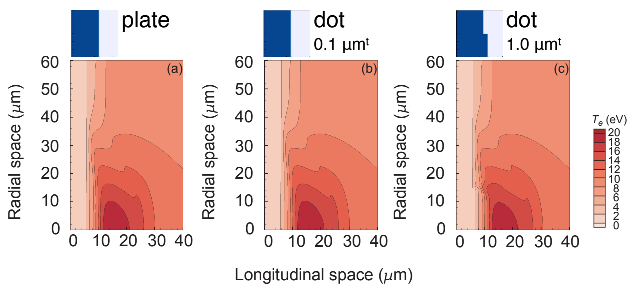
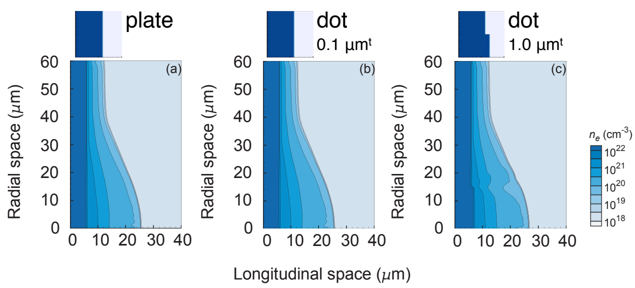


Fig. 7. Geometries of the initial targets of **(a) solid** and **(b,c) dots** with 100 nm (b) and 1 μm (c), respectively. The laser pulse intensity is 1 x 10^{11} W/cm^2 with the pulse duration of 150 ps.

Electron temperature



Electron density



Radiation intensity

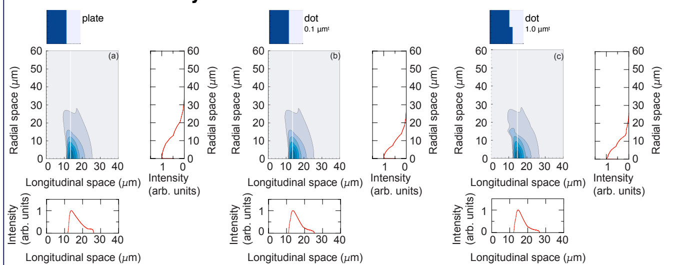


Fig. 8. Distributions of the electron temperatures, electron densities, and EUV sources at different target geometries of solid, 100-nm thickness dot, and 1-μm thickness dot. The evaluated source sizes of ~15 μm and intensities are almost same at the laser intensity of 1 x 10^{11} W/cm^2 with the pulse duration of 150 ps and focal spot diameter of 30 μm. The electron temperature and its density were calculated to be T_e ~ 20 eV and n_e ~ 10^{20} cm^{-3} (n_i ~ 10^{19} cm^{-3}) at the peak the EUV radiation intensity. As a result, the dot target would be useful for high brightness source with the source size of the order of 10 μm. It is noted that the 2-D numerical plasma parameters and source intensity are calculated by a star-2D code.

4. Summary

We have investigated a 13.5-nm high brightness source for mask metrology.

- The optimum plasma parameters and expanded plasma volume, which corresponds to the source size, have been evaluated.
- The magnetic field strength was calculated to be 0.2 T in the source position by use of permanent magnet with a surface magnetic field of 1.2 T.
- The effect of self-absorption at 13.5 nm due to high opacity was almost neglected and the EUV CE was observed to be 1-1.2% at the pulse duration of 150 ps.

Acknowledgements

A part of this work was performed under the auspices of Ministry of Education, Culture, Science and Technology, Japan (MEXT). We are also grateful to the Cooperative Research Center and the Venture Business Laboratory (VBL) of Utsunomiya University for providing the laser system. One of the authors (T.H) also acknowledges support from Research Foundation for Opto-Science and Technology.